Amendments to the Specification:

Please replace the paragraph beginning on page 1, line 3 with the following amended paragraph:

This application is a continuation-in-part of co-pending U.S. Patent Application No. 09/599,168, filed on June 22, 2000, entitled "THREE-PORT FILTER AND METHOD OF MANUFACTURE," by Scott M. Hellman et al., now U.S. Patent No. 6,343,166, the entire disclosure of which is incorporated herein by reference.

Please replace the paragraph beginning on page 4, line 3 with the following amended paragraph:

However, for many applications, it is desirable to obtain a high accuracy, thermally compensated optical multiple-port package that can be relatively inexpensive, reliable, and have a low insertion loss. Additionally, a package design should be adequate not only to mechanically protect the fragile optical components, but also to compensate for and minimize the thermally induced shift in spectral performance. Further, it is desirable to obtain a multiple-port package, such as six port packages, with the same qualities since they further reduce costs, reduce size, and also result in reduced insertion loss. Thus, there exists a need for such optical packages and a process for manufacturing such optical packages, which is miniaturized, has a low insertion loss, is inexpensive to manufacture, and which results in a device having reliable, long-term operation.

Please replace the paragraph beginning on page 4, line 14 with the following amended paragraph:

————The present invention provides an improved optical assembly (e.g., optical filter assembly) with a low insertion loss (IL) and provides an assembly of the optical components, such as input ferrules, collimating lenses, and filters, utilizing bonding adhesives in a manner which allows the alignment of the individual components relative to one another with a precision and a manufacturability that makes it possible to produce commercial devices having five, six or more ports. This had heretofore had not been achieved. In one aspect, the invention includes an improved input

ferrule and filter holder which permits active alignment and bonding through the utilization of UV and thermally curable adhesives and improved thermal curing to greatly reduce relevant internal stresses in the subassembly so formed. For assemblies having multiple pairs of fibers (e.g., five or more port devices), the invention also provides improved fiber ferrule designs, alignment methods, and methods to permit the manufacture of devices that have low IL, operate over a wide temperature range, are reliable, and cost effective.

Please replace the paragraph beginning on page 6, line 1 with the following amended paragraph:

In a preferred method of manufacturing the invention, subsequent to the UV curing process, the assembly is cured through a stress relaxation cycle at about 40-50°C for two to four hours followed by a thermal curing cycle of about 95 to 110°C for one to two hours.

Please replace the paragraph beginning on page 6, line 15 with the following amended paragraph:

The methods and apparatus described herein facilitate the manufacture of a multiple-port optical device which results in several advantages. For example, in a six port device having two pair of optical fibers in the input collimating assembly, one filter operates with at least two transmitted light beams and splits the beams into at least two reflected and two transmitted beams, thereby reducing by half the number of optical filters, collimating lenses and enclosure units. Thus, for example, the same six-port filtering package can be used in the multiplexing and de-multiplexing operations of a DWDM module incorporating concatenated six-port packages. A typical DWDM module includes from two to eight six-port packages. In this case, the number of filter chips, collimating lenses, and fiber ferrules will be reduced by one-half compared to using three port packages.

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Please replace the paragraph beginning on page 7, line 24 with the following amended paragraph:

a4

      Figs. 4 and 4A are _an_ enlarged vertical cross-sectional and right end view, respectively, of a prior art ferrule employed in a prior art filter assembly;

Please replace the paragraph beginning on page 9, line 12 with the following amended paragraph:

a7

      Fig. 14B is a cross-sectional exploded view of a fiber-ferrule assembly using alignment washers;~~and~~

Please replace the paragraph beginning on page 9, line 27 with the following amended paragraph:

a8

      Fig. 16I is a schematic diagram of an eight-port add/drop package; _and_

Please replace the paragraph beginning on page 10, line 2 with the following amended paragraph:

a9

      Referring initially to Figs. 1 and 2, a brief description of an optical element (e.g., filter) subassembly 10 is first presented. The invention is described and illustrated using an exemplary three-port filter device, however, the invention also applies to multiple-port devices such as six-port devices. For multiple-port devices, the number and position of fibers in ferrule 16 changes accordingly. The dual fiber collimating and filtering subassembly 10 includes an outer cylindrical metal housing 12, which is bonded at 13 (Fig. 1) around input and reflection optical fibers 18 and 20, respectively. Housing 12 surrounds an insulating cylindrical boro-silicate or fused silica sleeve 14 (Fig. 2) within which there is mounted a dual capillary glass ferrule 16 receiving an input optical fiber 18 and a reflective optical fiber 20. The ends of fibers 18 and 20 in ferrule 16 face a collimating lens 22, such as, for example, a GRIN lens, which has polished facets on the input end, and (as seen in Fig. 2) which face and align with the ends of optical fibers 18 and 20 held in place by ferrule 16. Lens 22 collimates light from input fiber 18 into parallel rays, transmitting them to an optical element

which may be a thin film filter 24, a birefringent crystal, or other appropriate optical element. The end of the collimating lens 22 that is closest to the filter 24 is referred to as the output end of collimating lens 22. A filter holder 26 is mounted to the end 21 of the collimating lens 22 according to the method of the present invention and includes an axial aperture 27 allowing light from lens 22 to impinge upon filter 24 and the reflective light to be directed to reflective optical fiber 20. Filter holder 26 also secures filter or crystal 24 in alignment with the collimating lens 22 with aperture 27 extending between the filter 24 and lens 22. The fiber-ferrule 16, lens 22, and insulating sleeve 14 are collectively referred to as an input collimating assembly 35. Collimating assembly 35 may also include cylindrical metal housing 12. A similar single fiber collimating assembly structure is collectively referred to as an output collimating assembly 35' and is shown in Fig. 3.

Please replace the paragraph beginning on page 10, line 27 with the following amended paragraph:

Before describing the manufacture of the subassembly 10 forming a part of an overall three-port filter, a three-port filter 30 is briefly described. Fig. 3 is also representative of a multiple-port device, however, for a multiple-port device, the number and position of fibers in ferrules 16 and 39 changes accordingly. As shown in Fig. 3, three-port filter 30 includes an outer cylindrical metal sleeve 32 into which subassembly 10 is mounted and secured by a cylindrical interface of solder and/or welding material 31 applied to the solder joint as seen in the schematic diagram of Fig. 3. Solder and/or weld material 31 may be applied through suitable apertures 32A in metal sleeve 32. The output signal from filter 24 is received by an aligned collimating output lens 34 similarly secured within a boro-silicate or fused silica glass sleeve 36 surrounded by a metal sleeve 37 which, in turn, is mounted within the interior of outer protective sleeve 32 utilizing a cylindrical solder interface 33. The output lens 34, ferrule 39, glass sleeve 36, and metal sleeve 37 form the output collimating assembly 35'. An output optical fiber 38 couples to the desired wavelength output signal from three-port filter 30 to the communication link in which the three-port filter 30 is installed. Thus, for example, the three-port filter 30 may be employed to receive a plurality of wavelengths from input optical fiber 18, pass a single output wavelength to output fiber 38, and return the remaining signal

wavelengths to reflective optical fiber 20. The method of assembling subassembly 10 and its structural elements[[,]] are unique and-is described in detail below. Further, the specific method of aligning output collimating assembly 35' within sleeve 32 will also be described below.

Please replace the paragraph beginning on page 12, line 3 with the following amended paragraph:

Capillaries 42 and 44 of ferrule 40 are spaced apart a distance "D1,"[[,]] as shown in Fig. 4A that with the coned length provided by prior art ferrules as shown in Fig. 4, results in such excessive micro-bending of the optical fibers and resultant insertion losses. The alternate ferrule construction in which a single elliptical capillary is provided for receiving adjacent optical fibers and having a similar input cone construction suffers even more from the bending problem. In order to greatly reduce the insertion loss due to the undesirable S-bending of input fibers, an improved ferrule 16 of the present invention, which forms part of the subassembly 10 as seen in Figs. 1 and 2, is employed and is described in Figs. 5 and 5A.

Please replace the paragraph beginning on page 13, line 5 with the following amended paragraph:

The fibers are epoxied within the ferrule 16 with an epoxy adhesive such as, for example, 353 ND EPO-TEK epoxy adhesive available from Epoxy Technology, Billerica, Massachusetts, and cured at about 110°C for one and one-half hours. It is preferable to post-cure the assembly at 125-130°C for one-half hour to reduce moisture absorption. The end-face 28 of the ferrule with inserted and bonded optical fibers isare ground and polished to produce approximately 8° angle elliptical facet to the axis of the ferrule. Ferrule 16 is then cemented within the surrounding thermally insulating glass sleeve 14 (Fig. 2) to form input collimating assembly 35. Prior to the insertion of the ferrule 16 into sleeve 14, the lens 22 has been installed and cemented in place. The ferrule is aligned with a gap "G" (Fig. 2) of about 1 to 1.5 μm between the ends of the lens 22 and the ferrule to allow the axial and rotational active alignment of the ferrule to the lens 22 by rotating the ferrule within sleeve 14 and axially positioning it to accommodate the surface angle of the lens 22, which may run between 7.8° to

8.1°. For a three-port assembly, a signal is applied to the input fiber 18 while monitoring the output

of the GRIN lens within sleeve 14. For a multiple-port assembly, such as used in a six-port device,

the alignment process is similar;[[,]] however, signals are applied to each of the input fibers and the

ferrule is axially and rotationally positioned to optimize the alignment for all of the signals. This

assures the minimum insertion loss and maximum signal coupling between the optical fibers and the

input collimating lens 22, which subsequently receives the filter holder and filter therein as now

described in connection with Fig. 6.

Please replace the paragraph beginning on page 13, line 25 with the following amended paragraph:

Referring now to Fig. 6, the subsequent positioning of filter 24 and filter holder 26 onto end

21 of the lens 22 is described. Matching the AOI of the filter 24 with the separation distance (SD) of

the fibers 18 and 20 is important. A filter 24 with a desired AOI is selected for use in the assembly

10. An input collimating assembly 10 is selected having a ferrule 16 which has an SD that

corresponds to the AOI of filter 24. The SD is accurately measured, preferably within 0.5 μm, and

the filter holder 26 is mounted on the selected input collimator assembly 35. The matching process in

the case of the four-fiber ferrule, used in six-port devices, is preferably performed as follows. The

SD of one of the pairs of fibers is matched to the filter AOI. The alignment match for the second pair

of fibers is provided automatically when the structural tolerances described above for the capillaries

and fibers have been satisfied. Therefore, it is important for the SD for each pair of fibers to be

approximately equal. Preferably the SD tolerance for each pair of fibers is within 0.5 μm. The

tolerances are further discussed below in discussion of Figs. 14 and 15.

Please amend the paragraph beginning on page 16, line 1 with the following amended paragraph:

During this alignment process, lens 22 and its sleeve 12 are mounted in an XYZ micro-

adjustable stage of conventional construction to hold the projecting end of lens 22 in cavity 25 of

holder 26. Once the optimum angular position of the filter holder 26 to lens 22 is determined, the

filter holder 26 is raised axially away from the lens (while maintaining the angular relationship) to allow access to the side wall of lens 22. While separated, preferably four or more drops of bonding adhesive are~is~ positioned on the outer peripheral circumferential surface of the end 21 of lens 22, with care being taken not to touch drops of the epoxy adhesive to the lens end face surface. The filter holder 26 is then lowered over the lens 22, wiping the adhesive in the annular space between cavity 25 and lens 22. Next, the XZ axis of the stage may be further adjusted while monitoring signals applied to the input and reflective optical fibers 18 and 20 to assure a minimum insertion loss. Similarly, the YZ axis of the stage may also be adjusted while monitoring the signals to assure proper alignment and a minimum reflected insertion loss of no greater than about 0.3 dB. A variety of UV and thermally curable epoxies were tested, and it was determined that the bonding adhesive which worked unexpectedly well was commercially available EMI-3410, which is a UV and thermally curable filled adhesive available from Electronic Materials, Inc., of Breckenridge, Colorado.

Please amend the paragraph beginning on page 16, line 18 with the following amended paragraph:

By providing a gap of approximately 50 μm between the inner surface of cylindrical aperture 25 of filter holder 26 and the outer diameter of lens 22, the optical axis of the lens can be precisely aligned with the optical axis of filter 24. Filter holder 26 is~being~ adjustable within an angle α_2 of less than about 1.0°, as shown in Fig. 6. This active alignment of the lens 22 and filter holder 26 is achieved by the movement of the lens 22 in the XZ and YZ planes, as shown in Fig. 6, utilizing a standard micro-stage (i.e., micropositioner). In one embodiment of the invention, one or more sources of ultra violet radiation such as sources 60 and 61 are employed to expose the bonding adhesive at the interface between holder 26 and lens 22 to ultraviolet radiation to cure the bonding adhesive sufficiently such that the desired relationship between the lens 22 and filter 24 is fixed until the adhesive is finally thermally cured.

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Please replace the paragraph beginning on page 16, line 29 with the following amended paragraph:

α¹⁵

As seen by the diagram of Fig. 7, by injecting ultra violet radiation from source 60 into the exposed end of filter 24, ultra violet radiation (indicated as 63) is dispersed as the UV radiation propagates transversely through the filter and into the adhesive layer 55 (Fig. 6), causing frontal polymerization of the adhesive due to UV light propagating through the filter. In most instances, the UV radiation 63 from source 60 through filter 24 will, upon an exposure of about 20 seconds at a distance of about 2.5 cm between the source and the filter 24, result in sufficient UV curing of the adhesive to fix the filter holder to the lens 22. In addition to exposing the adhesive 55 through filter 24 utilizing a UV light source 60, an additional UV light source 61 can be employed to direct UV radiation 63 through the gap G2 between the lower annular end of filter holder 26 and the top annular surface of sleeve 12 with 40 second exposures for a total exposure of about 100 seconds of UV radiation to cure the adhesive in the annular area of gap G1 at the lower end of filter holder 26. After the UV curing, which tends to temporarily induce stresses typically of from 200 to 300 psi or higher in the subassembly, thermal cure stress release and curing is provided as described below. Before such curing, however, input and output signals are monitored to assure that the reflected insertion loss (IL) remains less than about 0.3 dB and thermal change in IL is below about 0.05dB. The UV from light source 61 can be rotated around the periphery of the subassembly during successive exposures. The UV light can be delivered also through slots or openings formed into the lateral sides of the filter holder 22 as described below.

Please amend the paragraph beginning on page 17, line 19 with the following amended paragraph:

α¹⁶

The UV sources 60 and 61 have spectral emissions, as illustrated in Fig. 8, which shows the spectrum of a mercury light source. Fig. 9 illustrates the experimentally determined UV transmission spectrum of such a light source through a bulk filter chip of the kind used in the filter 24 illustrated in Fig.ure 6. The convolution of these spectra indicates that a sufficient portion of the UV light spectrum propagates to the bond layer through the filter 24 and that the duration of the UV cure cycle

results in a nearly zero change of insertion loss over a period for from 630 to 700 seconds. The UV
initiated cure induces initial stresses due to polymerization shrinkage. For a typically highly filled
epoxy adhesive with a limited volume of shrinkage (on the order of 0.2%), the induced stress can be
as high as 300 to 600 psi. The stresses induced by the UV curing, which fixes the alignment of the
filter to the collimating lens 22, are relieved and the bonding adhesive 55 further cured during thermal
curing of the subassembly 10 in a conventional oven which is controlled to provide the stress
relaxation and thermal cure cycles as illustrated in Fig. 10.

Please replace the paragraph beginning on page 19, line 3 with the following amended paragraph:

As shown in Fig. 11, a filter holder 26´ is shown, which is substantially identical to filter
holder 26 with respect to the provision of a cylindrical gap by its lower cylindrical aperture 25´ for
adjustment of the filter holder to the lens; however, the lower end of filter holder 26´ includes a
plurality of apertures such as longitudinally extending, radially inwardly projecting slots 70 spaced
around the periphery of the filter holder and communicating with cylindrical opening 25´ within the
filter holder 26´. Four to six slots 70 have been found acceptable. Once a filter 24 is mounted in
place as described above in connection with filter holder 26, holder 26´ receives epoxy as in the
previously described embodiment, and the lens is raised and adjusted with respect to filter 24
contained within filter holder 26´ in the same manner as in the first embodiment. The light source 61,
however, is moved around the periphery of the filter holder 26´ directing UV radiation into slots 70
defining downwardly projecting, spaced apart legs 72 between such slots such that UV radiation is
dithered into the cylindrical side walls of lens 22 which serves to further disperse the UV radiation
uniformly within the annular space containing bonding adhesive 55. By providing spaced radially
extending elongated slots 70 or other suitably shaped apertures extending through the side wall of the
lower section of filter holder 26´, a light path is provided for UV radiation to the inner cylindrical
aperture 25´ receiving the end of lens 22. In one embodiment, four slots 70 spaced at 90° intervals
around the lower section of holder 26´ were provided. This results in improved uniform UV
exposure to facilitate the UV curing of adhesive 55. In this embodiment, it is unnecessary to expose

the bonding adhesive utilizing a light source 60 through the filter since the bonding adhesive is uniformly exposed utilizing radiation from light source 61. Once the subassembly 10´, as shown in Fig. 12, is completed, it is assembled into the resultant three-port filter package 30´ in a conventional manner.

Please replace the paragraph beginning on page 20, line 9 with the following amended paragraph:

One important aspect of a multiple-port device is the tolerance for the position of the optical fibers in the fiber ferrule 16. The core of an optical fiber has a diameter of only about 9.5μm. Consequently, a 1μm shift or error in the position of the fiber can cause the IL to be unacceptable. Therefore, great care must be taken to ensure the total tolerance in the positioning of the fibers. To achieve these tolerances, the fibers should be pre-selected to provide the core concentricity within a tolerance of preferably about 1.0 μm, and more preferably about 0.5 μm, and most preferably about 0.1 μm; cladding diameter of 125μm within a tolerance of preferably about 1.0μm, and more preferably about 0.5 μm, and most preferably about 0.1 μm; and the ovality tolerance of preferably less than about 0.8%, and more preferably about 0.4%, and most preferably about 0.12%. Concentricity is the deviation of the center of the optical fiber core from the center of the fiber. Ovality is defined as the difference between the largest and smallest diameter of the fiber divided by the average diameter of the fiber (i.e., (D1-D2) *2 /(D1+D2) where D1 and D2 are the largest and smallest diameter of the fiber). The pre-screening and selection of the fibers for one or more of these characteristics havehas yielded the unexpected result of providing an assembly in which the fibers and other component parts can be assembled and aligned in a manner that can be reliably repeated and manufactured for commercial applications. Prior to the realization of this unexpected result, there were no commercially available optical packages having greater than three ports, and no commercially available six port packages. Regarding ferrule capillary tolerances, the simplest "square" capillary ferrule is preferably characterized by a tolerance of the output end of the capillary of 252 μm +/- 2 μm as the distance between two parallel sides and more preferably 251 μm +/- 1 μm and most preferably 250.5 μm +/- 0.5 μm. Similar tolerances are preferred for the other capillary shapes and

configurations. Further, the tolerance of the fiber position must be maintained throughout the manufacturing, packaging, and environmental conditions the device must endure. The methods and apparatus to achieve these tolerances are a subject of the present invention and are discussed below.

Please amend the paragraph beginning on page 21, line 6 with the following amended paragraph:

Although some prior art devices may initially achieve the desired tolerances for the position of optical fibers, the prior art often fails when the device is subject to stresses, strains and environmental conditions that cause the fibers to shift sufficiently to exceed the tolerances. Causes of these stresses include: 1) viscous flow of adhesive involving the fibers, 2) curing of the adhesives that bond the fibers to the ferrule, and[[,]] 3) thermal stress due to the final packaging operations or environmental testing conditions. During manufacture, the devices are subject to heat such as from solder used to encase the devices in a protective metal sleeve 32. In use, the devices are subject to environmental conditions and must remain operational over a qualification temperature range from -40°C to 85°C (an industry standard temperature range). Therefore, one aspect of the invention relates to a four-fiber-ferrule that satisfies the above-mentioned tolerances.

Please replace the paragraph beginning on page 21, line 17 with the following amended paragraph:

Ferrules are generally cylindrical boro-silicate or fused silica components with one, two, three or more capillaries for receiving the optical fibers. Ferrules 16 were discussed above in discussion of Figs. 2 and 3;[[,]] however, the capillaries for six-port devices are preferably different. The shape of the drawn capillaries and the illustrative fabricating techniques allow fibers to be not only symmetrically separated from the central axis of the ferrule, but be properly guided and constrained as well. This minimizes the repositioning caused by the adhesive flow and the thermally induced change in the separation distance between two pairs of the input and reflective fibers. The capillaries provide precision parallel positioning inside the ferrule and bonding of the fibers and thereby provide a reliable constraint of the fibers. Preferably, the fibers touch the nearest adjacent fiber or have a gap

between the fibers of not more than about $0.5\mu m$. This helps to fix the position of the fibers. It is also preferred that the fibers do not twist around each other over the first 10 to 15 mm before the fibers enter the ferrule to reduce stress and/or fiber repositioning. An illustrative assembly process includes the following steps. The fibers are stripped of the protective coating and cleaned for a length of about 5 cm of the fiber end. The fibers are dipped into adhesive (e.g., Epo-Tek 353 ND). The stripped fiber ends are then fed through the capillary until the fiber coatings just reach into the cone end portion of the ferrule. Additional adhesive is applied to the fibers if needed, and the adhesive is allowed to wick through the entire capillary. An adhesive such as 353 ND adhesive with viscosity (at room temperature) of about 3000 cPs (centipoise), or other suitable adhesive, can be used. The predicted gaps in the capillaries shown correspond to this viscosity. A higher viscosity adhesive (5000 to 10000 cPs) may be used if the gaps are slightly larger. An increase in temperature when inserting the fibers inside the capillaries decreases the viscosity of the adhesive. Thus, having various viscosities and temperatures, we can provide a better positioning of the fibers and minimize their repositioning after cure. In general, a suitable viscosity can be determined using the Hagen-Poiseuille equation modeling viscous flow in a capillary with optical fibers positioned in the capillary.

Please replace the paragraph beginning on page 22, line 14 with the following amended paragraph:

The assembly is cured, an 8-degree angle is polished into the ferrule and anti-reflective coating is applied. The bond layers between the fibers and surrounding ferrule are extremely thin (preferably less than about 1-1.5 μm) to minimize thermal stress and movement. Various embodiments of the ferrule capillaries of the present invention are illustrated in Fig. 13A to 13H and Fig. 14A to14E.

Please replace the paragraph beginning on page 22, line 19 with the following amended paragraph:

Fig. 13A shows a cross-sectional view of a ferrule 16 with a rounded square or rounded rectangular capillary 130 and closely packed optical fibers 131a, 131b, 131c, and 131d. The rounded square capillary provides a fixed SD, while the rounded rectangular~~rectangle~~ capillary can make the

SD variable. The rounded corners and closely packed fibers make this a good design for several reasons. The shape of the capillary along with the closely spaced fibers 131 effectively prevents movement of the fibers 131 prior to curing and also reduces thermal stress on the fibers after curing. The curvature of rounded corners 130a preferably has a smaller radius than the outer surface of fibers 131. More preferably, the corners 130a are 90-degree angles and thus form a true square or rectangle capillary. Therefore, for purposes of this specification, "substantially rectangular" refers to a capillary cross section where the radius of the corners is less than or equal to the radius of the enclosed optical fibers. Gap G4 is where the fiber comes closest to touching, or actually touches, the wall of capillary130. Gap G4 is preferably less than about 0.5 μm, and more preferably less than about 0.1 μm, and most preferably zero (i.e., the fiber touching the wall of the capillary). The gap G6 between the closely adjacent fibers 131a and 131b (and also fibers 131c and 131d) is similarly small (i.e., preferably less than about 1.0 μm, 0.5 μm, or zero μm). The gap G5 is also preferably small (i.e., less than about 1.0 μm, 0.5 μm, or zero μm) however,[[,]] the gap G5 between the distant adjacent fibers 131a and 131d may be larger to achieve a desired SD as illustrated in the following figures. The closely packed fibers also provide a secondary advantage in that only a small amount of adhesive is required in the capillary 130 and therefore less thermal stress is exerted on the fibers 131 due to the unequal coefficient of thermal expansion (CTE) between the fibers and the adhesive. Even the adhesive in the larger gap G5 has been found to have minimal effect in causing stress or shifting of the optical fibers due to thermal expansion and contraction. This capillary design tends to prevent shifting of the fibers and prevents rotation of the fibers due to the flow of adhesive prior to cure (e.g., fiber 131d is unlikely to rotate to the position of fiber 131a, and fiber 131a is unlikely to rotate to position 131b, etc.).

Please replace the paragraph beginning on page 23, line 26 with the following amended paragraph:

Several other exemplary capillary designs include the dual-oval capillary (Fig. 13B), the clover-leaf or four-circular capillary (Fig. 13C), the six-fiber rectangular capillary (Fig. 13D), the two wafer-ferrule (Fig. 13E and 13F), the four-fiber rectangular capillary (Fig. 13J), the dual rectangular

capillary (Fig. 13K), the variable dual rectangle capillary (Fig. 13L), the dual oval capillary (Fig. 13M), the mixed capillary (Fig. 13N) and the alignment washer design (Figs. 14A and& B). For simplicity, the same reference numbers are used for corresponding features in each of the Figures.

Please replace the paragraph beginning on page 24, line 8 with the following amended paragraph:

Referring now to Fig. 13B, the shape of dual-oval capillary 132 resembles two adjacent ovals and the capillary 132 encloses the optical fibers 131. Portions of capillary 132 form a constraining arc 132a of approximately 120° to 180° around fibers 131. The gap G4 between the surface of the fibers 131 and the proximate wall of the capillary 132 is preferably less than about 1.5 μm, and more preferably less then about 1.0 μm, and most preferably less than about 0.5 μm. Similarly, the gap between closely adjacent fibers G6 is also preferably less then about 1.5 μm, and more preferably less then 1.0 μm, and most preferably less then about 0.5 μm at the closest point. The gap G5 between the variably distant adjacent fibers G5 preferably ranges from 0.5 μm to about 300 μm depending on the position of the two oval capillaries. The diagonal pairs, such as fibers 131a and 131c, are formed into pairs of input and reflective optical fibers. The dual-oval capillary may be expanded to three or even four adjacent ovals, if desired, to form multi-oval capillaries. However, in the multi-oval capillaries, diagonal pairs of optical fibers are preferable.

Please replace the paragraph beginning on page 24, line 28 with the following amended paragraph:

Fig. 13D illustrates a rectangular capillary 130 enclosing six fibers 131. Again, the gaps[[,]] G4, G5, and G6 are preferably as small as possible to prevent movement of the fibers. The gaps are therefore preferably less than about 1.5 μm, and more preferably less then about 1.0 μm, and most preferably less than about 0.5 μm. In this embodiment, the fibers have two separation distances. The diagonal fiber pairs (i.e., 131a, 131c and 131b, 131d) have matching separation distance. However, the fiber pair, 131e and 131f, have a smaller separation distance. While this configuration may be of

less use with thin film filter assemblies, this configuration is useful for certain crystal based assemblies such as isolators.

Please replace the paragraph beginning on page 27, line 1 with the following amended paragraph:

Generally, over-etching of the V-grooves is not a problem. If the V-grooves are over-etched, only a uniform vertical shift in the wafers is induced. Of course, if the V-grooves are etched excessively, the fibers and alignment pins may have room to move or reposition. Fig. 13H illustrates the relative position of fibers and alignment pins and V-grooves. The V-groove on the left easily restrains the movement of the fiber. However, the V-groove on the right side provides very little restraint on the fiber and is therefore less desirable.

Please replace the paragraph beginning on page 28, line 7 with the following amended paragraph:

There is Aanother design for achieving variable separation distance is illustrated in Fig. 13J. In this design, a rectangular capillary 130 supports four fibers 131. The fibers are positioned against the walls of the capillary 130 and therefore the separation distance is controlled by the width of the capillary 130. The gaps, G4 and G6, are preferably less than about 1.5 μm, and more preferably less then about 1.0 μm, and most preferably less than about 0.5 μm. However, the horizontal gap G5 between fibers may be as wide as desired. In other words, gap G5 is the shortest or minimum distance between the cladding of adjacent fibers 131b and 131c.

Please replace the paragraph beginning on page 28, line 15 with the following amended paragraph:

Yet another design is the dual-rectangle capillary illustrated in Fig. 13K. The capillaries 130 may be manufactured to tolerances of less than 1.0 μm using currently known techniques and therefore the separation distance between the fibers can be closely controlled. The dimensions of the capillaries 130 are specified to be 2.0 μm wider and taller than the dimensions of the fibers 131. The

tolerance for the capillaries 130 is 2.0 μm. Therefore, there is room for inserting the fibers into the capillaries and while limiting the repositioning of the fibers.

Please replace the paragraph beginning on page 29, line 3 with the following amended paragraph:

Fig. 13M illustrates another dual capillary design similar to the design of Fig. 13K. However, in this instance, the capillaries are ovals instead of rectangles. The same fabrication techniques and tolerances apply to this embodiment.

Please replace the paragraph beginning on page 29, line 17 with the following amended paragraph:

Yet another process and apparatus for positioning optical fibers inside of a ferrule uses alignment washers to precisely position the fibers. This process is illustrated in Figs. 14A and B. The process uses alignment washers 140 shown in Fig. 14A. Washer 140 is shown having four apertures 141 for receiving optical fibers;[[,]] however, it is easily scalable to larger numbers of optical fibers. Alignment washer 140 allows precision fiber placement into a ferrule 16 using simple and highly manufacturable components. Photolithography technology may be used to manufacture the washers 140 with the precisely positioned apertures 141 and spacing between them. The diameter of apertures is preferably about 126 μm which provides approximately 0.5 μm gap between the fiber and the wall of the aperture. The tolerances for the location of the apertures are also preferably less than about 1.0 μm and more preferably less than about 0.5 μm for each pair of the input and reflective fibers. For example, the tolerance for the distance "D4" between the apertures 141d and 141b is preferably 0.5 μm. The same is applicable to the distance "D5" between apertures 141a and 141c. However, the tolerance for the distance "D6" between adjacent apertures such as 141a and 141b is preferably less than about 1.0 μm and more preferably less than about 0.5 μm. A photo-resistive material is used to fabricate the washers 140. Any other technique may be used to form the washer as long as the necessary tolerances are achieved. The washers 140 are used as optical fiber-guiding and

constraining devices. The capillaries described above generally result in restricting fiber movement or shifting to less than about 0.5 μm.

Please replace the paragraph beginning on page 30, line 7 with the following amended paragraph:

Turning to Fig. 14B there is shown a cross-section view of the washers 140, fibers 142, and ferrule 16. Fibers 142 are inserted through first washer 140a, through ferrule 16, and through a second washer 140b. Ferrule 16 may have a conventional cylindrical capillary 130. However, the invention may be adapted for use with most capillaries regardless of shape. At this step of the process, it may be helpful to pre-heat the assembly to aid in the installation and precise placement of the fibers 142. The assembly may then be cooled to room temperature to hold the fibers 142 in position while adhesive is applied. Washers 140 are bonded to the end-faces of ferrule 16. In the case of a ferrule having a cone portion for receiving fibers (see Fig. 5), the washer 140 is preferably bonded at the base of the cone portion where the capillary 130 meets the cone portion. The ferrule capillary 130 is filled with a liquid adhesive via the gap created by the flat portion 143 of washer 140 and either UV cured or thermally cured. The flat portion 143 may also be used to align the fibers at each end of the ferrule prior to curing the adhesive. When both flat portions are aligned, then the fibers are also aligned. The completed assembly is processed the same as a conventional ferrule; the end-face is ground to approximately an 8° angle, polished, and an AR coating is applied. Filter AOI and Fiber SD are discussed next.

Please replace the paragraph beginning on page 30, line 23 with the following amended paragraph:

For all of the fiber capillaries discussed above, it is important to achieve accurate SD so that the SD can be accurately matched with a filter AOI as discussed in the next section. Further, when manufacturing a fiber-ferrule having multiple pairs of fibers, it is important for SD for all of the pairs to be the-approximately equal (with a tolerance of about 0.5μm) since this tends to make the active alignment process easier and more successful.

Please replace the paragraph beginning on page 31, line 23 with the following amended paragraph:

Generally, matching of filter AOI and fiber SD is done by creating a database of measurements for the different sets of the filter chips and the ferrules. First, filters are tested and characterized according to CWL and AOI. The measurements may be performed as follows. A filter is assembled into a filter assembly 10 or similar device so that a light signal may be directed onto the filter. A light signal is transmitted into input optical fiber 18, transmitted through the collimating lens 22 to filter 24. The output of filter 24 is monitored and the pass frequency or CWL of the filter is determined. The angle of the light signal impacting relative to the filter is adjusted until the desired output signal from filter 24 is achieved. Typically for the commercial thin film filters, the resulting AOI is between about 1.8° and 3°.

Please replace the paragraph beginning on page 33, line 1 with the following amended paragraph:

Input and output collimating and filtering assemblies are affixed inside protective sleeve 32. Output fiber-ferrule collimating assembly 35' is manufactured in nearly the same way as input collimating assembly 35. However, depending on the application, fewer of the fiber pigtails 38 may be needed. Also, it is preferred to use an aspheric collimating lens (which may be a molded aspheric lens) instead of a GRIN lens in the output collimating assembly 35'. Aspheric lenses have advantages in application to 6 port and higher port devices as compared to GRIN lenses. First, aspheric lenses have a long working distance, defined as the distance from the front focal point to the front surface of the lens. For multiple-port devices, the input and output collimating assemblies should have their focal points coincide in order to optimize the insertion loss. This point should also coincide with the filter coating surface of the filter. For multiple-port collimating assemblies that are on the substrate side of the filter, the working distance must be large enough, or the filter must be thin enough, so that the focal point can be placed on the filter coating surface of the filter. If GRIN lenses alone are used only, then the filter thin films and substrate would need to be very thin (on the order of 240 times the refractive index of the substrate, in μm). At this thinness, the filter films and substrates would have

limitations associated with film stress and also high susceptibility to breakage, cracking, etc. during manufacturing. Aspherical lenses have working distance on the order of 2 mm which allows a standard filter and substrate thickness of about 1.5 mm (and larger) to be used. Therefore, a preferred configuration includes a four fiber ferrule, a GRIN or asphere lens, a bandpass (thin film filter) coating, a substrate, an asphere, and a dual fiber ferrule. The following configuration is also possible while still optimizing insertion loss: a four fiber ferrule, an asphere lens, a substrate, a bandpass (thin film filter) coating, a GRIN or asphere, and a dual fiber ferrule.

Please replace the paragraph beginning on page 33, line 25 with the following amended paragraph:

Another advantage of aspheric lenses is the flexibility in focal length. In order to keep the angle of incidence to the filter low, a longer focal length of the lens is desirable. This is relatively easy to accomplish with an aspheric lens. Molded asphere lenses are available with many different focal lengths at a low cost. For GRIN lenses, to make the focal length longer, the index profile must change, which represents a significant departure from the standard doping process. It is difficult and costly to obtain GRIN lenses at arbitrary focal lengths. All of the above makes aspherical lenses more attractive for this application.

Please replace the paragraph beginning on page 34, line 19 with the following amended paragraph:

The previous discussion has related to how to manufacture multiple-port devices such as four-fiber ferrules and six- and eight-port filtering packages. The following discussion relates to further applications of these devices and additional advantages of the invention.

Please replace the paragraph beginning on page 34, line 23 with the following amended paragraph:

Turning first to Fig. 16A, there is shown a schematic diagram of a four-port filtering assembly which includes a first input fiber 160a, a first reflective fiber 160b coupled to a second input fiber

160c, and a second reflective fiber 160d. Also illustrated are ferrule 16, lens 22, and filter 24. In operation, a light signal is input through first input fiber 160a, collimated by lens 22 and partially reflected by filter 24. The reflected signal is received by first reflective fiber 160b and communicated to second input fiber 160c. The signal is again collimated by lens 22 and partially reflected by filter 24 and finally received by second reflective fiber 160d which can communicate the signal to ana optical communications system, network or a desired destination. Features of this device provide enhanced performance which is useful in optical communication systems.

Please replace the paragraph that begins on page 35, line 24 with the following amended paragraph:

In another embodiment, a single filter assembly 161 may be used to gain flatten the signals from two amplifiers 162. Fig. 16C shows a schematic view of filtering assembly 161 coupled to two amplifiers[[,]] 162a and 162b. A light signal is input through fist input fiber 160a and reflected by gain-flattening filter 24. The reflected signal travels through first reflective fiber 160b to first amplifier 162a. The amplified signal travels back to filter assembly 161 through second input fiber 160c where it is again reflected by gain-flattening filter 24 and output through second reflective fiber 160d to second amplifier 162b.

Please replace the paragraph beginning on page 36, line 1 with the following amended paragraph:

Fig. 16D is an opto-mechanical schematic of a five-port filter 163. The operation of the filter is very similar to the assembly of Fig. 16A;[[,]] however, this five-port filter includes an output collimating assembly for receiving the signal transmitted through the filter 24. Filter 24 may be any of a variety of thin film filters, such as, for descriptive purposes, a narrow band-pass filter. A light signal is input by first input fiber 160a, collimated by lens 22 and partially reflected by filter 24. The selected narrow band portion of the signal is transmitted through the filter 24 to transmitted fiber 160e. The reflected portion of the signal is communicated through first reflective fiber 160b and

second input fiber 160c and reflected again by filter 24. The twice reflected signal is then output by
second reflective fiber 160d and the isolation from the transmitted frequency is as high as 24-30 dB.

Please replace the paragraph beginning on page 36, line 12 with the following amended paragraph:

In yet another embodiment, the filtering package is coupled to heat sink ports or terminals 165
to dissipate excess signal energy. In this embodiment, illustrated in Fig. 16E, filter 24 may be any of
a variety of thin film-type filters such as a band-pass filter or gain-flattening filter. A first input signal
is transmitted through first input fiber 160a, collimated by lens 22 and partially reflected and partially
transmitted by filter 24. The transmitted portion is transmitted through lens 34 to first transmitted
fiber 160e which is presumably coupled to a communications system. The reflected portion of the
first input signal is reflected back through lens 22 to first reflective fiber 160b which is coupled to a
first terminal 165a. Terminals 165 are heat dissipation devices commonly known in the art which
harmlessly dissipate the waste energy. A similar path is followed by a second light signal that is
transmitted through second input fiber 160c. The transmitted portion of the signal is transmitted to
second transmitted fiber 160f and the reflected waste energy portion is channeled to a second terminal
165b via second reflective fiber 160d.

Please replace the paragraph beginning on page 36, line 25 with the following amended paragraph:

Fig. 16F illustrates another embodiment with integrated waste energy heat sink ports.
However, in this embodiment, the heat sink terminals 165 are coupled to the transmitted fibers 160e
and 160f. The reflected signals are output through first and second reflective fibers 160b and 160d
and presumably connected to a communications system.

Please replace the paragraph beginning in page 38, line 12 with the following amended paragraph:

The DWDM module 170 also multiplexes signals. Starting with the second input fiber I2 of package 171a, a signal of wavelength λ_1 is transmitted through filter 24a to transmitted fiber T5 and coupled to package 171b. In package 171b, a signal of wavelength λ_2 is similarly input and transmitted through filter 24b. Filter 24b reflects wavelength λ_1 and thereby causes both wavelengths to be multiplex and communicated to package 171c. In package 171c, wavelength λ_3 is added to wavelengths λ_1 and λ_2. The signal containing all three wavelengths is communicated to package 171d where wavelength λ_4 is added.